

United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park NC 27711,

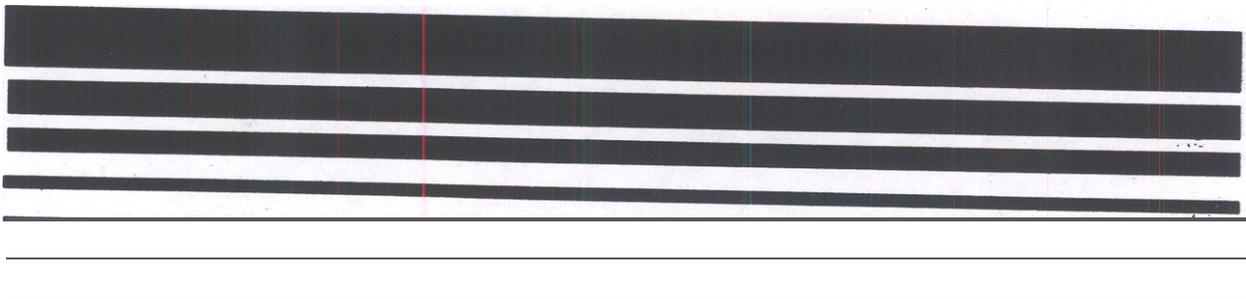
EPA-454/R-94-035
December 1994

Air



Clean Air Act Ozone Design Value Study: Final Report

A Report to Congress





The Clean Air Act Ozone Design Value Study

Final Report

Office of Air Quality Planning and Standards
U.S. Environmental Protection **Agency**
Research Triangle Park, NC 27711

DISCLAIMER

This **report** has been reviewed by the **Office** of Air Quality Planning and Standards, U.S. **Environmental** Protection Agency, and has been approved for publication. Mention of trade names or commercial products is not intended to constitute endorsement or recommendation for use.

Table of Contents

1 EXECUTIVE SUMMARY	1-1
INTRODUCTION	1-1
National Ambient Air Quality Standard for Ozone	1-2
Ozone Design Values	1-2
Regulatory History of Design Values	1-3
EPA Design Value Methodology.....	1-3
THE OZONE DESIGN VALUE STUDY	1-4
Spatial Representativeness	1-6
Temporal Representativeness	1-6
ALTERNATIVE OZONE DESIGN VALUE ESTIMATION METHODS	1-8
USE OF TIME-SERIES MODELS	1-10
PUBLIC OUTREACH EFFORTS..	1-11
OTHER CONSIDERATIONS	1-12
Adjusting for Transported Ozone Levels	1-12
Adjusting for Meteorological Variability	1-13
PEER AND PUBLIC REVIEW	1-14
MAJOR FINDINGS	1-17
CONCLUSIONS	1-19
REFERENCES	1-21
2 INTRODUCTION	2-1
OZONE STANDARDS AND DESIGN VALUES	2-1
National Ambient Air Quality Standard for Ozone	2-1
Implementation of the Ozone NAAQS: Estimating the Expected	
Exceedance Rate	2-2
Ozone Design Values	2-3
Estimating Design Values	2-4
THE OZONE DESIGN VALUE STUDY	2-7
Spatial Representativeness	2-9
Temporal Representativeness	2-10
Reasonable Indicator Criteria	2-10
Other Design Value Issues	2-10
STRUCTURE OF THE REPORT	2-11
REFERENCES	2-12
3 BACKGROUND	3-1
CHEMISTRY OF OZONE FORMATION	3-2
DISTRIBUTIONAL CHARACTERISTICS OF TROPOSPHERIC OZONE	3-6
Monitoring Ambient Ozone Concentrations	3-6
Spatial Distribution	3-6
Temporal Distribution	3-9

	Seasonal Patterns	3-9
	Diurnal Patterns	3-17
	Year-to-Year Variation	3-17
	Other Technical Issues	3-20
	SUMMARY..	3-2 1
	REFERENCES	3-2 1
4	OZONE DESIGN VALUE METHODOLOGIES	4-1
	OZONE GUIDELINE DESIGN VALUE METHODS	4-1
	EPA Table Look-up Method	4-1
	Use of Statistical Distributions	4-2
	Fitting Methods	.
	Lognormal Distributions	4-5
	Extreme Value Theory Approximations	4-6
	Tail Exponential and Related Approaches	4-7
	Conditional Probability Approach	4-8
	OTHER DESIGN VALUE APPROACHES	4-9
	California Method for Computing Recurrence Rate Values	4-9
	EPA Tabular Method Extended to Multiple Years	4-10
	Control Strategy Design Values	4-10
	SUMMARY..	4-11
	REFERENCES	4-1 ²
5	EVALUATION APPROACHES FOR OZONE DESIGN VALUE METHODS	5-1
	INTRODUCTION	5- 1
	OZONE AIR QUALITY DATABASE	5-1
	Spatial Distribution of Ozone Monitors	5-2
	Trends in Ozone Monitoring Coverage	5-3
	TIME-SERIES MODELING APPROACH	5-3
	Tie-Series Literature Review	5-3
	Concentration Tie-Series Models	5-6
	Exceedance Time-Series Models	5-7
	Computation of the Distribution of the Kth Highest Value	5-8
	Time-Series Model Development	5-9
	Basic Form of the Daily Maximum 1-hour Ozone Tie-Series	
	Model	5-11
	Model Evaluation	5-18
	SUMMARY	5-18
	REFERENCES	5-2 0
6	COMPARISONS AMONG ALTERNATIVE DESIGN VALUE METHODS	6-1
	ALTERNATIVE DESIGN VALUE METHODS	6-1
	Breiman Tail Exponential Method	6-1
	California Air Resources Board Method	6-2
	Distribution Fitting Method	6-2
	Percentile Method	6-3

COMPARISONS USING AMBIENT OZONE DATA	6 - 3
Selected Metropolitan Area Results, 1989-91	6-3
Comparisons For All Ozone Sites, 1987-89	6-10
Comparisons Among Multi-year Tabular Method Design Value Estimates	6-11
Multi-year Design Value Estimates in Selected Cities	6-17
Atlanta	6-18
C h i c a g o	6-18
New York City	6-18
Summary of Findings from the Air Quality Design Value Comparisons . .	6-21
TIME-SERIES MODELING SIMULATION RESULTS	6-22
Methodology	6-22
Comparison of Alternative Design Value Estimation Methods	6-24
Comparison of Biases of 3-Year Design Values	6-26
Comparison of Standard Deviations of 3-Year Design Values . .	6-28
Comparisons of Tail-Exponential Multi-Year Methods	6-30
Effect of Averaging Period on Alternative Design Value Methods	6-32
Surrogate Design Values	6-36
Summary of Conclusions from the Tie-Series Modeling Study	6-38
REFERENCES	6-42
7 THE ROLE OF METEOROLOGY IN OZONE FORMATION'	7-1
METEOROLOGICAL INFLUENCES ON OZONE CONCENTRATIONS	7-1
Insolation	7-2
Ventilation	7-2
Transport	7-4
Indirect Measures	7-4
ADJUSTING OZONE CONCENTRATIONS TO ACCOUNT FOR METEOROLOGICAL INFLUENCES	7-7
Regression Methods	7-8
Classification Methods	7-10
Methods for Defining Categories	7-10
Adjustment Procedures Based on Meteorological Categories . .	7-12
Other Adjustment Methods	7-15
SUMMARY AND CONCLUSIONS	7-18
REFERENCES	7-28
8 ASSESSING THE IMPACT OF TRANSPORTED OZONE AND PRECURSORS	8-1
CHRONOLOGY OF A MULTI-REGIONAL OZONE EPISODE, JUNE 17- 20, 1987	8-1
ADJUSTING OZONE DESIGN VALUES FOR TRANSPORT	8-7
SUMMARY	8-11
REFERENCES	8-11
9 DETECTING TRENDS IN OZONE DESIGN VALUES	9-1
STATISTICAL APPROACHES TO TREND ANALYSES	9-2

	Linear Model Approaches	9-4
	Nonparametric Methods	9-6
	Extreme Value Theory Approaches	9-8
	TIME-SERIES MODELS	9-10
	OZONE TRENDS ADJUSTED FOR METEOROLOGY	9-11
	SUMMARY AND CONCLUSIONS	9-11
	REFERENCES	9-13
10	ALTERNATIVE AIR QUALITY INDICATORS	10-1
	OZONE NAAQS RELATED INDICATORS	10-1
	ALTERNATIVE AIR QUALITY INDICATORS	10-3
	TEMPORAL VARIABILITY IN OZONE INDICATORS	10-10
	SPATIAL VARIATIONS IN OZONE CONCENTRATIONS	10-16
	Analysis of Monitoring Data	10-16
	Spatial Indicators of Air Quality	10-17
	SUMMARY	10-21
	REFERENCES	10-24
11	PUBLIC OUTREACH EFFORTS	11-1
	OVERVIEW OF PUBLIC MEETING COMMENTS	11-1
	Increase Robustness of the Design Value	11-3
	Adjust for Annual Meteorological Differences	11-3
	Compliance Test for Attainment	11-4
	Measurement Interference and Bias	11-4
	Size and Location of Ozone Monitoring Network	11-5
	Transport from Nearby Areas	11-5
	Refine Meteorological Models	11-5
	SUMMARY OF PUBLIC COMMENTS ON DRAFT REPORT	11-6
	Distinction Between Statistical Population Parameters and Estimated Parameters	11-7
	Increase Stability of the Design Value Estimator	11-8
	Attainment Test	11-10
	Adjust Design Values for Annual Meteorological Fluctuations	11-11
	Influence of Transport from Nearby Areas	11-12
	Influence of Spatial Variability in Ozone Concentrations	11-13
	Response to Previous Public Comments	11-13
	SUMMARY OF PEER REVIEW COMMENTS ON DRAFT REPORT	11-13
	REFERENCES	11-17
12	SUMMARY OF FINDINGS	12-1
	MAJOR FINDINGS	12-2
	CONCLUSIONS	12-5
	REFERENCES	12-6

List of Tables

1-1.	Ozone classifications specified in the 1990 Clean Air Act Amendments.	1-1
1-2.	Ozone design value rank based on number of years of data.	i-4
1-3.	Impact on ozone area classifications of varying the number of years when estimating the ozone design value using the EPA tabular method.	1-7
1-4.	Average and maximum design values as estimated for the period 1989-91 by each method	1-10
2-1.	Ozone design value rank,	2-5
2-2.	Hypothetical example of ozone design value determination (case with two 0, sites in an area, each year at least 75 percent complete).	2-6
2-3.	Ozone classifications specified in the 1990 Clean Air Act Amendments.	2-7
3-1.	Ozone monitoring season by state.	3-18
4-1.	Ozone Design Value Rank Based on Number of Years of Data	4-2
5-1.	Comparison of simulated and ambient ozone design values for sites in New York and Houston, 1988.	5-19
6-1.	Average and maximum design values as estimated for the period 1989-91 by each method	6- 5
6-2.	Comparison of Number of Areas with Multi-year Tabular Method Ozone Design Values Equal to or Greater than 0.125 ppm	6-13
6-3.	Ozone Nonattainment Area Classifications	6-15
6-4.	Impact on Ozone Area Classifications of Varying the Number of Years when Estimating the Ozone Design Value Using the EPA Tabular Method	6-16
6-5.	Comparison of number of nonattainment areas in Clean Air Act classification categories with number of areas in classification ranges based on 1989-91 ozone monitoring data.	6-17
6-6.	Sites studied in time series comparisons of design values.	6-23
6-7.	Results from 1000 time series simulations of three-year design value estimates from alternative design value estimation methods in live selected metropolitan areas.	6-2 5
6-8.	Comparison of two methods of applying the Breiman tail-exponential method to estimation of three-year design values (1000 three-year simulations).	6-31
6-9.	Simulation comparison of the effect of averaging period on new York area site 340230006 design values estimated by various methods.	6-33
6-10.	Comparison of limiting values for alternative design value estimators from alternative design value estimation methods in five selected metropolitan areas	6-35
6-11.	The 95-percentile as a surrogate ozone design value (3000 one-year and 1000 three-year simulations).	6-37
6-12.	Estimation of ozone design value from the 95th percentile surrogate.	6-40
7-1.	Meteorological variables potentially associated with ozone formation.	7-3
8-1.	Transport Adjusted Ozone Design Values, 1988-90	8-10
8-2.	Comparison between Air Quality Design Value and Transport Adjusted Design Value Derived Ozone Area Classifications, 1988-90.	8-11

10-1. Number of expected exceedances at design value sites within ozone area classification categories for areas initially designated nonattainment under the Clean Air Act Amendments of 1990.	10-2
10-2. Average Number of Expected Exceedances at All Sites in Designated Nonattainment Areas, 1987-89 , . . . ,	10-2
10-3. Alternative Air Quality Indicator Values for 1987-89	10-5
10-4. Correlation Matrix for Alternative Indicators, 1987-89'	10-7
10-5. Relative Ranks of Alternative Air Quality Indicators	10-8
10-6. Correlation Matrix for Spatial Indicators in Los Angeles	10-17
I 1-1. Matrix of Public Meeting Written Comments by Subject Area . ,	11-2

List of Figures

1-1.	Map depicting ozone design values at all sites in the northcentral states of Indiana, Illinois, Michigan and Wisconsin, 1987-89 .	1-5
1-2.	Actual and adjusted trends in number of days on which ozone concentrations exceed 0.12 ppm in the Chicago area (adapted from Kolaz and Swinford, 1990).	1-15
1-3.	Adjustment of ozone trend based on number of days above 90° F (Source: Jones, 1992).	1-16
1-4.	Actual and meteorologically adjusted ozone trends in the 99th percentile of the daily maximum 1-hour ozone concentration for Chicago, 1981 - 1990 (adapted from Cox and Chu, 1992).	1-17
2-1.	Initial ozone nonattainment area designations and classifications under the Clean Act Amendments of 1990.	2 - 8
3-1.	Typical base ozone chemistry evolution profiles for NO, NO₂ , and ozone, and ozone chemistry with reduced reactive organic (ROG) emissions.	3 - 4
3-2.	Ozone monitoring network in the continental United States, 1990 .	3 - 7
3-3.	Second highest daily maximum 1-hour ozone concentration by year for all sites in the Los Angeles-Anaheim-Riverside, CA CMSA.	3-10
3-4.	95th percentile ozone concentration by year for all sites in the Angeles-Anaheim-Riverside, CA CMSA .	3-10
3-5.	Second highest daily maximum 1-hour ozone concentration by year for all sites in the Boston-Lawrence-Salem, MA-NH CMSA .	3-11
3-6.	95th percentile ozone concentration by year for all sites in the Boston-Lawrence-Salem, MA-NH CMSA .	3-11
3-7.	Second highest daily maximum 1-hour ozone concentration by year for all sites in the Chicago-Gary-Lake County, IL-IN-WI CMSA .	3-12
3-8.	95th percentile ozone concentration by year for all sites in the Chicago-Gary-Lake County, IL-IN-WI CMSA .	3-12
3-9.	Second highest daily maximum 1-hour ozone concentration by year for all sites in the Dallas-Ft. Worth, TX CMSA .	3-13
3-10.	95th percentile ozone concentration by year for all sites in the Dallas-Ft. Worth TXCMSA .	3-13
3-11.	Second highest daily maximum 1-hour ozone concentration by year for all sites in the Houston-Galveston-Brazoria, TX CMSA .	3-14
3-12.	95th percentile ozone concentration by year for all sites in the Houston-Galveston-Brazoria, TX CMSA .	3-14
3-13.	Second highest daily maximum 1-hour ozone concentration by year for all sites in the New York-Northern New Jersey-Long Island, NY-NJ-CT CMSA .	3-15
3-14.	95th percentile ozone concentration by year for all sites in the New York-Northern New Jersey-Long Island, NY-NJ-CT CMSA .	3-15
3-15.	Map depicting ozone design values at all sites in the northcentral states of Indiana, Illinois, Michigan and Wisconsin, 1987-89 .	3-16

3-16.	Map depicting ozone design values at all sites in the northeastern states of Connecticut, Massachusetts, New York and Rhode Island, 1987-89. . . .	3-16
5-1.	Map depicting location of the ozone monitoring sites that reported hourly ozone concentration data for at least one year during the period 1980 - 1990.	5-4
5-2.	Map depicting location of the 323 ozone monitoring sites that monitored each year during the period 1980 - 1990.	5-4
5-3.	Number of areas (CMSAs/MSAs/counties) reporting ozone data to AIRS by year.	5-5
5-4.	Example of variability of ozone daily maximum 1-hour concentrations.	5-10
5-5.	Log transform of daily maximum 1-hour concentrations at sample site. . . .	5-13
5-6.	LOWESS smoothing of the log of the daily maximum 1-hour concentrations at the sample site.	5-14
5-7.	LOWESS fits to ten years of ozone data at the sample site.	5-15
5-8.	Probability plot of ARIMA residuals at a site in the New York metropolitan area.	5-16
5-9.	Probability plot of ARIMA residuals at a site in the Houston metropolitan area.	5-17
6-1.	Average and maximum design values for monitors in the Chicago metropolitan area for alternative design value estimation methods.	6-6
6-2.	Average and maximum design values for monitors in the New York metropolitan area for alternative design value estimation methods.	6-7
6-3.	Average and maximum design values for monitors in the Los Angeles-South Coast Air Basin area for alternative design value estimation methods. . . .	6-8
6-4.	Comparison of design values estimated using the California Air Resources Board (CARB - Larsen) method with the fourth highest daily maximum 1-hour concentration at all sites in the Chicago and New York metropolitan areas, 1989-91.	6-9
6-5.	5th and 95th percentile differences for comparisons among alternative ozone design value estimation procedures.	6-10
6-6.	5th and 95th percentile differences among multi-year ozone design value estimates.	6-12
6-7.	Number of areas with multi-year tabular method ozone design values greater than or equal to 0.125 ppm.	6-14
6-8.	Trends in multi-year table look-up ozone design values in Atlanta, GA, 1980 - 1990.	6-19
6-9.	Trends in multi-year table look-up ozone design values in Chicago, 1980 - 1990.	6-19
6-10.	Trends in multi-year ozone design values in New York for all sites and sites with eleven years of data.	6-20
6-11.	Design value bias versus characteristic largest value.	6-27
6-12.	Standard deviation of design value affected by site and design value magnitude and method of computation.	6-29
6-13.	Effect of averaging time on design value estimated by three different methods at four locations.	6-34

6-14.	Limiting design value (CLV) versus average 3-year 95th percentile.	6-39
7-1.	Annual number of days on which the average daily maximum ozone concentration in the Philadelphia Ozone Network exceeds 0.085 ppb based yearly data run down the CART tree grown on 1979-1988 data	7-13
7-2.	Actual and adjusted trends in number of days on which ozone concentrations exceed 0.12 ppm in the Chicago area	7-16
7-3.	Actual and meteorologically adjusted ozone trends in Atlanta, Baltimore, Bakersfield and Baton Rouge, 1981-1991 (adapted from Cox and Chu, 1991).	7-17
7-4.	Actual and meteorologically adjusted ozone trends in Beaumont, Birmingham, Boston and Bridgeport, 1981-1991 (adapted from Cox and Chu, 1991).	7-19
7-5.	Actual and meteorologically adjusted ozone trends in Charlotte, Chicago, Cincinnati and Cleveland, 1981-1991 (adapted from Cox and Chu, 1991). . .	7-20
7-6.	Actual and meteorologically adjusted ozone trends in Columbia, Dallas, Denver and Detroit, 1981-1991 (adapted from Cox and Chu, 1991).	7-21
7-7.	Actual and meteorologically adjusted ozone trends in El Paso, Fresno, Hartford and Houston, 1981-1991 (adapted from Cox and Chu, 1991).	7-22
7-8.	Actual and meteorologically adjusted ozone trends in Los Angeles, Louisville, Miami and Milwaukee, 1981-1991 (adapted from Cox and Chu, 1991). . . .	7-23
7-9.	Actual and meteorologically adjusted ozone trends in Los Angeles, Louisville, Miami, and Milwaukee, 1981-1991 (adapted from Cox and Chu, 1991).	7-24
7-10.	Actual and meteorologically adjusted ozone trends in Muskegon, New York, Philadelphia, and Phoenix, 1981-1991 (adapted from Cox and Chu, 1991).	7-25
7-11.	Actual and meteorologically adjusted ozone trends in Tampa, Tulsa, and Washington, D.C., 1981-1991 (adapted from Cox and Chu, 1991)	7-26
8-1.	Isopleths of ozone daily maximum 1-hour concentrations for June 17, 1987.	8-3
a-2.	Isopleths of ozone daily maximum 1-hour concentrations for June 18, 1987. .	a-4
a-3.	Isopleths of ozone daily maximum 1-hour concentrations for June 19, 1987. .	8-5
8-4.	Isopleths of ozone daily maximum 1-hour concentrations for June 20, 1987. .	8-6
8-5.	Midwest region on July 17, 1987.	8-8
8-6.	Northeast region on July 7, 1988.	a-a
a-7.	Northeast region at 1400 EST on July 8, 1988.	8-8
8-8.	Northeast region at 2300 EST on July 8, 1988.	8-8
9-1.	Sample illustration of the use of confidence intervals to determine statistically significant changes.	9-3
9-2.	Comparison of meteorologically adjusted, and unadjusted, trends in the composite average of the second highest maximum 1-hour concentration for 43 MSAs , 1983-1992.	9-12
10-1.	Average number of expected exceedances versus the EPA DV for all sites, 1987-89	10-4
10-2.	Year to year variability in selected ozone air quality indicators. . . .	10-10
10-3.	Temporal variability in ozone indicators in Los Angeles and Houston.	10-11
10-4.	Temporal variability in ozone indicators in Chicago and Milwaukee. .	10-12
10-S.	Temporal variability in ozone indicators in New York and Baltimore.	10-13
10-6.	Temporal variability in ozone indicators in Philadelphia and Atlanta	10-14

10-7. Temporal variability in ozone indicators in Boston and Hartford.	10-15
10-8. Number of days on which the federal ozone standard was exceeded in 1989	10-18
10-9. Design values (fourth highest value in each three year period) for selected stations.	I O - 1 9
10-10. Comparison of annual ozone indicators.	IO-20
10-11. Comparison of indicators for overlapping three year periods	10-22
10-12. Comparison of indicators for overlapping three year periods normalized to 1980 values.	10-23